DETECTOR TECHNOLOGY

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TRANSPORTATION
COMMISSION

Kimley-Horn
and Associates, Inc.

Detector Technology

AGENDA

- General overview of detection technologies
- Arterial Applications
  - Signalized intersection
    - Vehicle and bicycle detection
  - Mid-block data collection
- Freeway Applications
  - Freeway data collection
  - Ramp metering
- Special Applications
- Technology Evaluation & Cost

Overview of Detection Technologies

Intrusive

- Inductive Loop
- Wireless Magnetometer
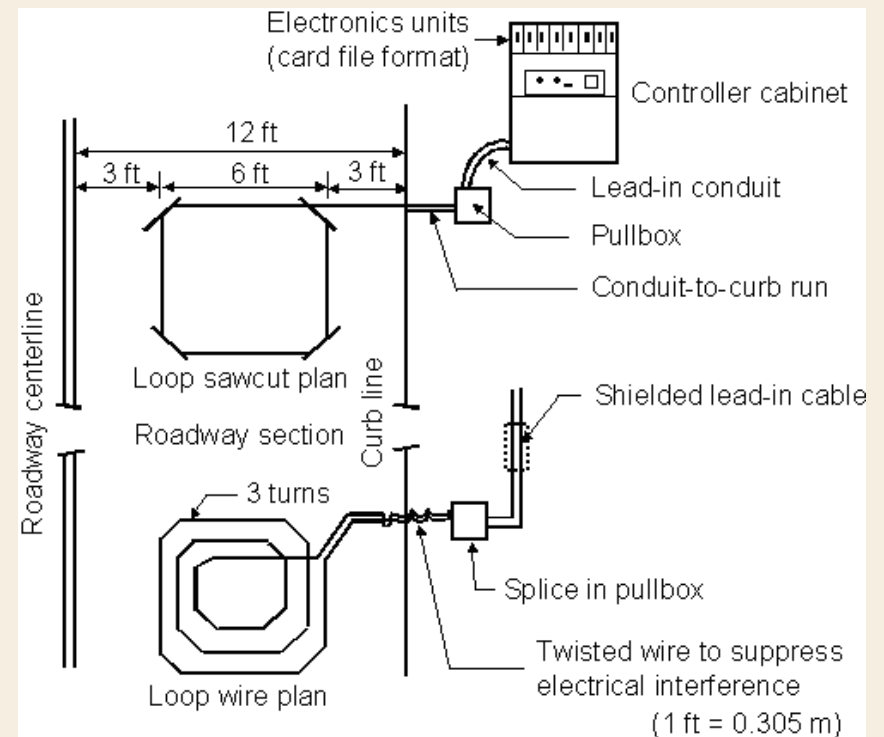- Microloop

Non-intrusive

- Video Image Detection
- Radar
- Microwave
- Sound
- Infrared

Inductive Loop

- Most widely used detection technology since 1960s

- Detects presence, passage, lane occupancy, speed

- One or more turns of insulated loop wire installed in slot in pavement

- Several types of loop configurations

Inductive Loop – cont.

- Electromagnetic field is created around wire
- Moving conductive metal object (i.e. vehicle, bicycle) passing through electromagnetic field disturbs field
- Frequency change exceeding a pre-set threshold results in presence call
- Call is sent to respective phase input in controller
- NEMA standards specify a satisfactory inductance range of 50-700 microhenries
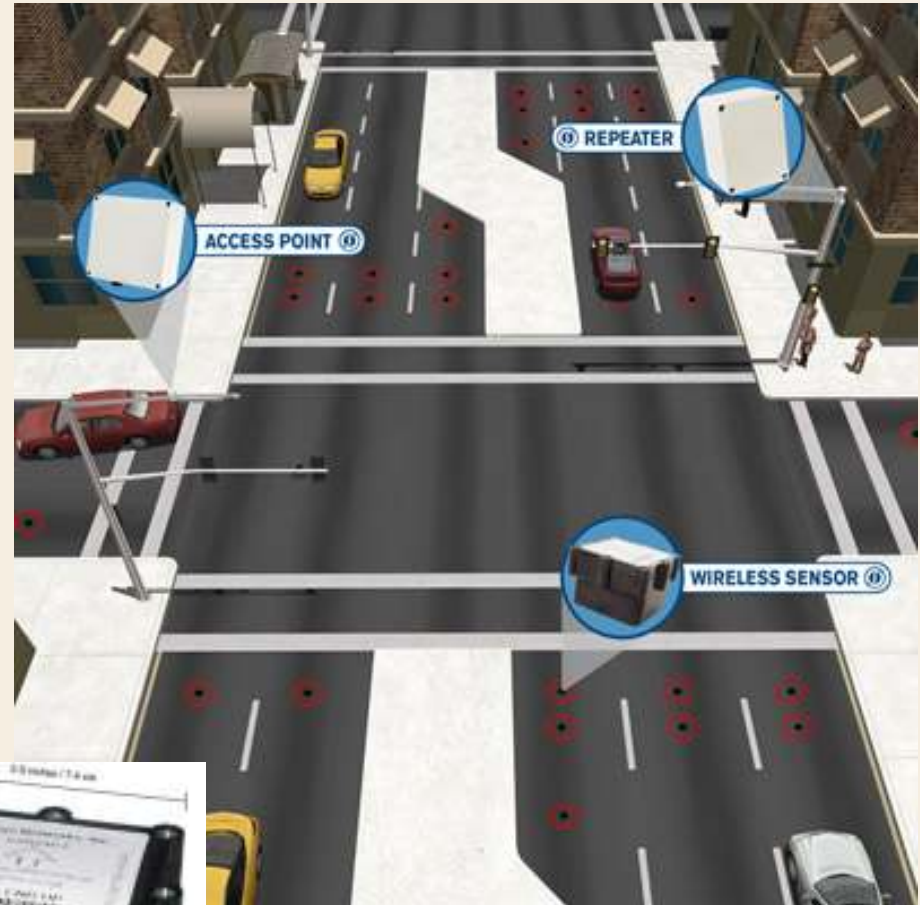
Inductive Loop configurations

Wireless Magnetometer

- Small in-pavement sensor
- Detects presence and passage from changes in ambient magnetic field
- Installed in roadbed
- Wireless communication with signal controller means no trenching and quick installation
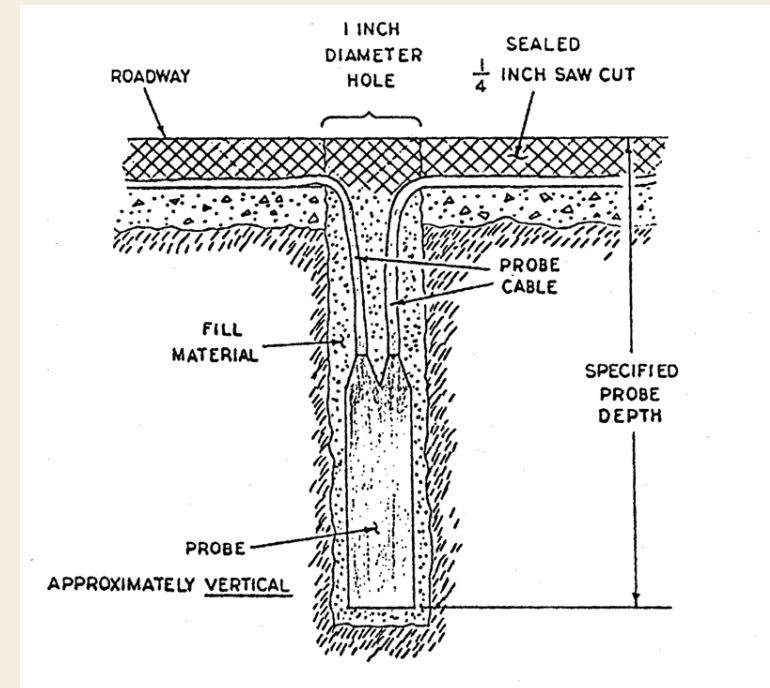
Source: *Sensys Networks, Inc.*

Microloop

- Detects presence, passage, occupancy, and speed

- Detects changes in ambient magnetic field

- Installed in conduit in roadbed
  - Can be installed and maintained from side of road

Source: *3M M701 Microloop Operations Manual*

Video Image Detection

- Fixed position video cameras mounted overhead or side fire
- Video Image Processor (VIP) system analyzes imagery using algorithms and converts into traffic data
- Uses change in image to detect traffic
- Detects presence, occupancy, speed, classification, and incident detection
- Requires adequate street lighting
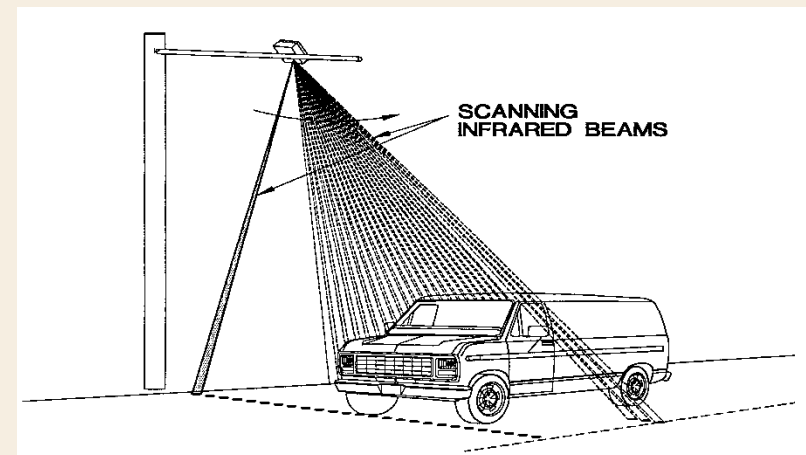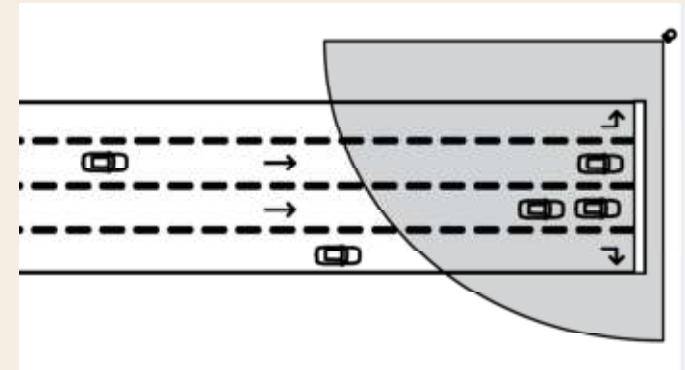- User defined detection zones

Video Image Detection

Source: *Econolite*

Radar

- Radar Presence Detector (RPD)
- Transmitted electromagnetic radar signal is reflected by a moving target (i.e. vehicle) in its path
- Detects occupancy, speed, classification, and some forms can detect presence
- Fixed position units mounted overhead or side fire

Source: *Electronic Integrated Systems, Inc. (EIS)*

Microwave

- Transmitted high-frequency microwave signal is reflected by a moving target (i.e. vehicle)

- Doppler shift between emitted and received frequency used to determine direction and speed of vehicle

- Detects presence, occupancy, and speed

- Fixed position units mounted overhead or side fire

Source: *Electronic Integrated Systems, Inc. (EIS)*

Sound

A Single SAS-1

Direction of Travel

RS L1 L2 L3 LS

Detection Zones

h

x

Source: *SmartTek Systems*

- Detects presence and passage
- Some units can detect speed
- Fixed position units mounted side fire
- Microphones aimed at traffic stream picks up noise from tires
- Ultrasonic detectors transmit sound at 25 KHz to 50 KHz

Infrared

- **Passive Infrared**
  - Detects passage and presence
  - Cannot detect speed
  - Uses energy sensitive photon detector to measure infrared energy emitted by objects in the detector's field of view

- **Active Infrared**
  - Detects passage, presence, and speed
  - Uses laser diode to transmit energy, some of which is reflected back into receiver when a vehicle enters view
  - Other types use light emitting diodes (LEDs) as signal source
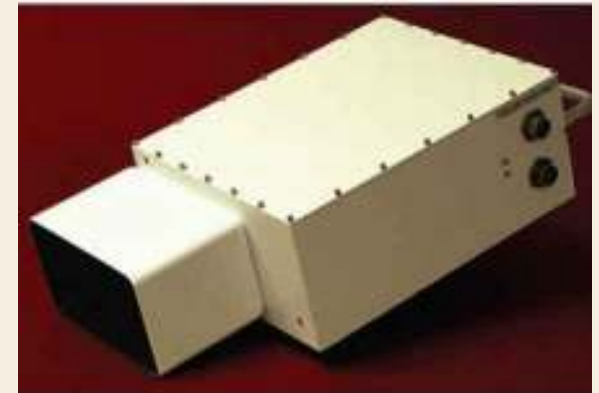
Applications

- **Arterial Application & Design**
  - Signalized Intersection
    - Vehicle and bicycle detection
  - Mid-block data collection
- **Freeway Application & Design**
  - Freeway data collection
  - Ramp Metering

Arterial Applications

- **Signalized Intersection**
  - Basic signal detection
    - Vehicular presence (stop bar)
    - Vehicular extension (advanced)
    - Bicycle presence/extension
  - Volumes and occupancy
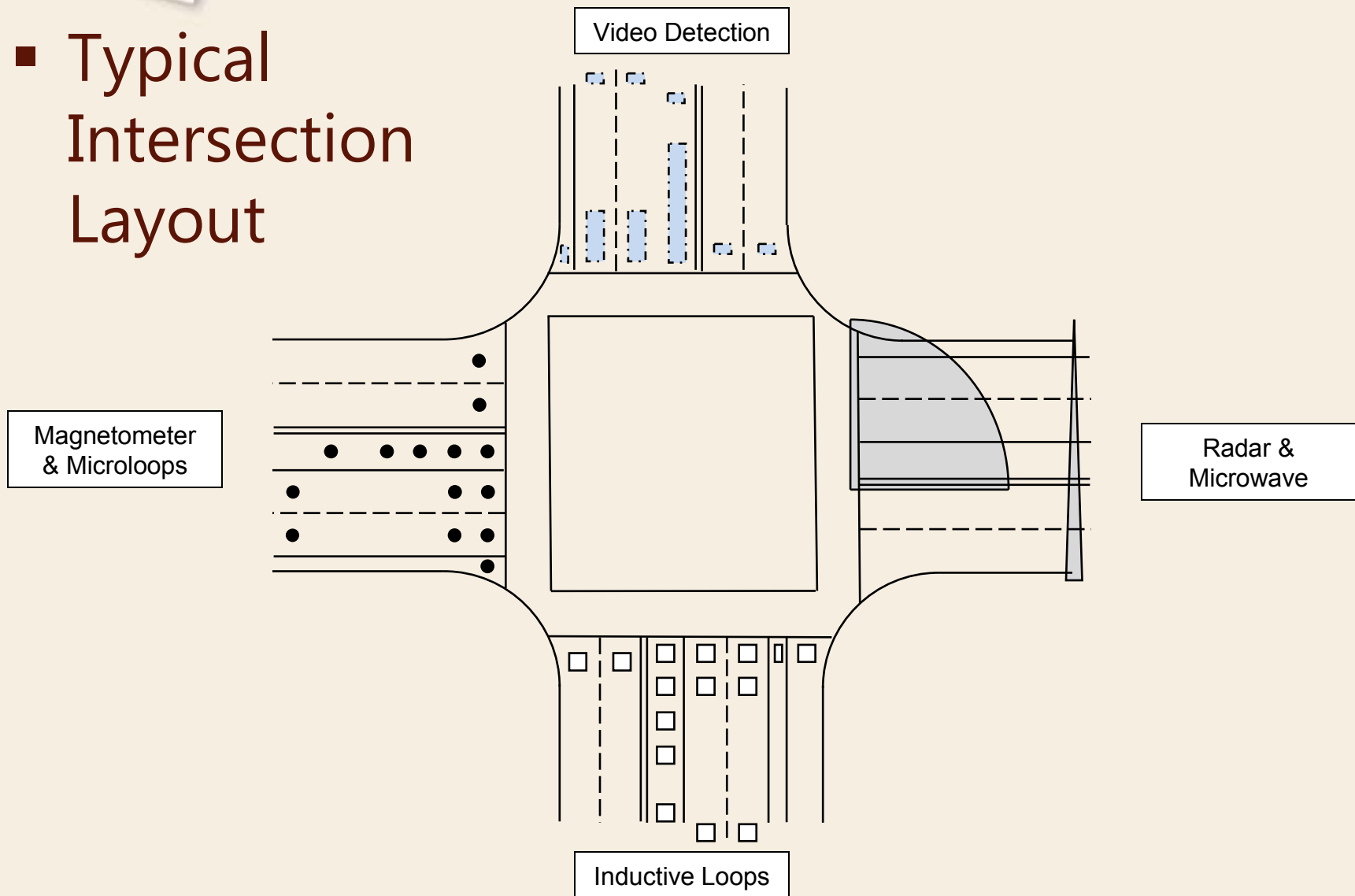   - Approach volumes and occupancy
    - Turning movement volumes

Arterial Applications

- Mid-block Data Collection
  - Volume
  - Speed
  - Travel Time
  - Occupancy

Signalized Intersection

- Typical Intersection Layout

Video Detection

Magnetometer & Microloops

Radar & Microwave

Inductive Loops

Signalized Intersection

- **Presence (Stop Bar) Detection**
  - Place call into controller
  - Long detection zone (18' to 42')
  - Typically single input per lane, although can have multiple lanes per input
  - Technologies
    - Inductive loops
    - Video
    - Magnetometers
    - Radar (Presence type)
    - Microloops

Signalized Intersection

- **Presence Detection, cont.**

  – Inductive loops

    - Typically 2-4 loops per lane
    - Single lead-in cable per lane
    - Different shapes and configuration: Round, square, diamond, rectangle
    - Sawcut in pavement or can use pre-formed type
    - Can install prior to final pavement lift to preserve loop and roadway
    - More sensitive "D-type" front loop for bicycles
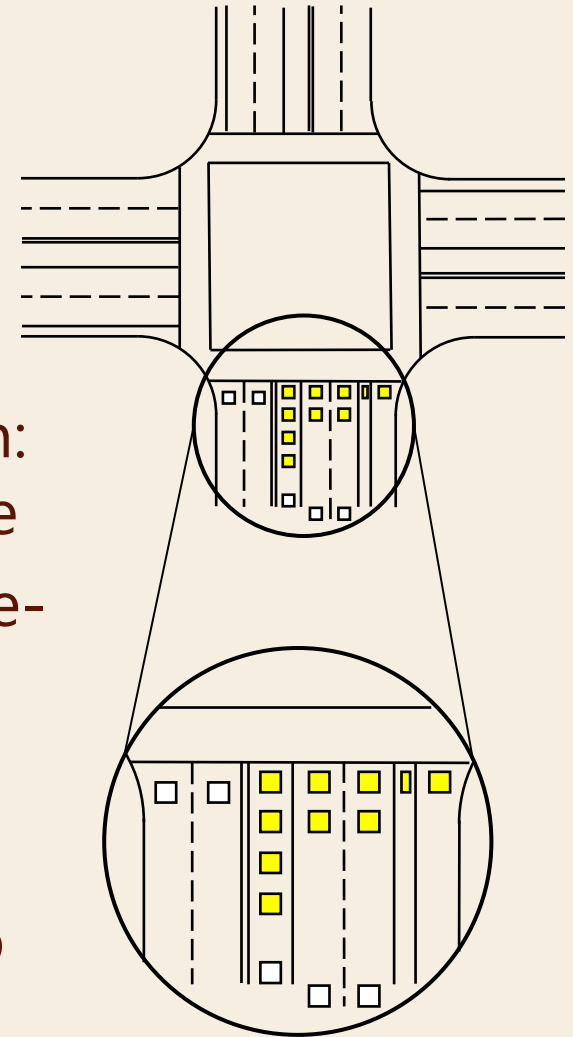
Signalized Intersection

- ## Presence Detection, cont.

  - ### Video

    - Usually single camera per approach
    - Zones drawn in desired location and to desired size
    - Camera angle important to capture all lanes effectively
    - Typically installed high on luminaire arm or extension pole on mast arm
    - Affected by light, glare, weather (rain, fog, wind)

Source: *Econolite*

Signalized Intersection

- **Presence Detection, cont.**
  - Magnetometers
    - Number of detectors to model same configuration as loops
    - Wireless to cabinet
  - Radar (Presence Type)
    - Single unit per approach, mounted on far side signal
    - Detection zone configured per lane, similar to video
  - Microloops- Not typically used for presence but could be installed per row of loops


Source: *Sensys Networks, Inc.*

Signalized Intersection

- **Advanced (Extension) Detection**
  - Call to extend the signal phase
  - Single detector/zone per lane
  - Through lanes and sometimes left
  - Can be used for counts and occupancy
  - Technologies
    - Inductive loops
    - Video
    - Magnetometers
    - Radar/Microwave
    - Others

Signalized Intersection

- **Advanced Detection, cont.**
  - Inductive loops
    - Typically single 6'x6' square or 6' round loop per lane
    - Single lead-in cable per lane for counts and occupancy
  - Video
    - Same camera for stop bar detection or separate camera
    - Narrow zone drawn per lane
    - Counts and occupancy per zone
   - Again, angle of camera important
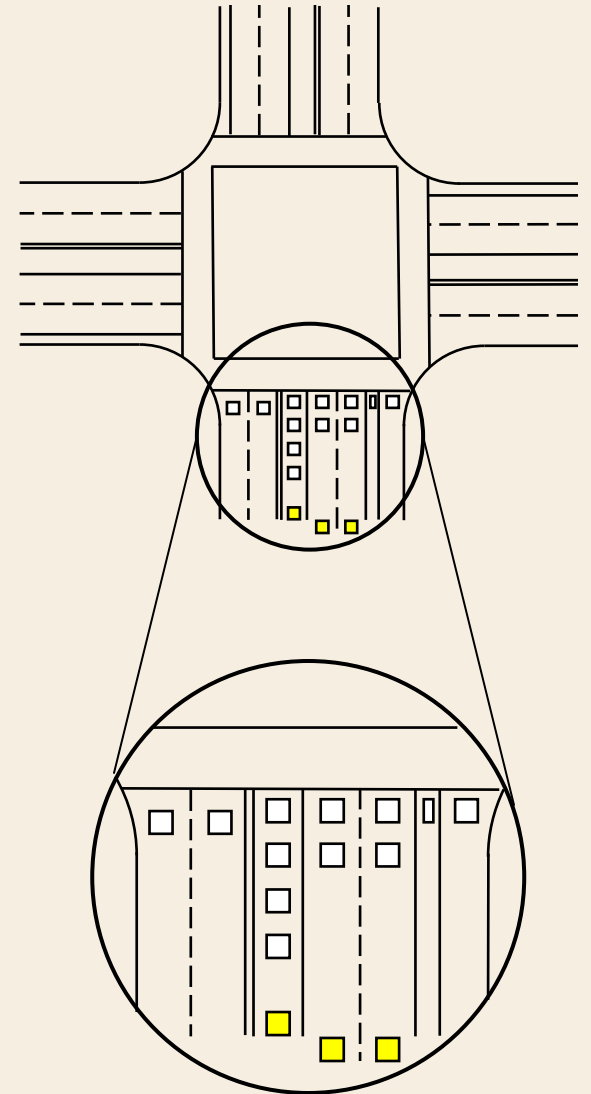
Signalized Intersection

- **Advanced Detection, cont.**
  - Magnetometers
    - Same as loops, usually single unit per lane
  - Radar/Microwave (Side fire)
    - Mounted on the side of road
    - Most systems automatically configure zones by lane
    - Can capture other direction also
  - Radar (Forward)
    - Single unit per approach
    - Mounted on approach mast arm
  - Others (Acoustic, Infrared) – Could be used but not common

Source: *Electronic Integrated Systems, Inc. (EIS)*
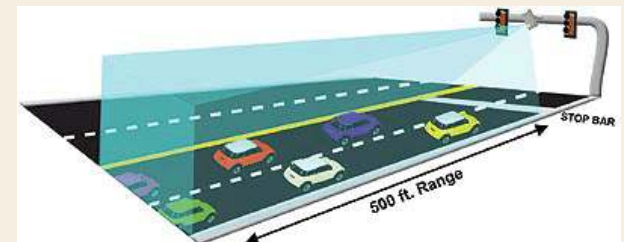
Source: *Wavetronix LCC*

Signalized Intersection

- Bicycle Presence/Extension
  - Single detection for presence/extension
  - Technologies
    - Inductive loops, video, magnetometers, radar, infrared
  - Inductive loop and magnetometers
    - Seperate loop or unit for lane
  - Video, radar, and infrared
    - Zone programmed with single unit, can be the same as for stop bar detection
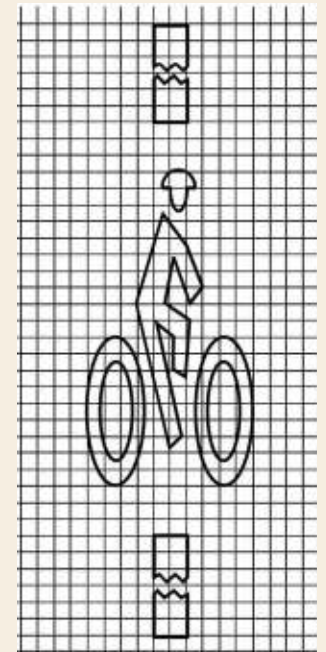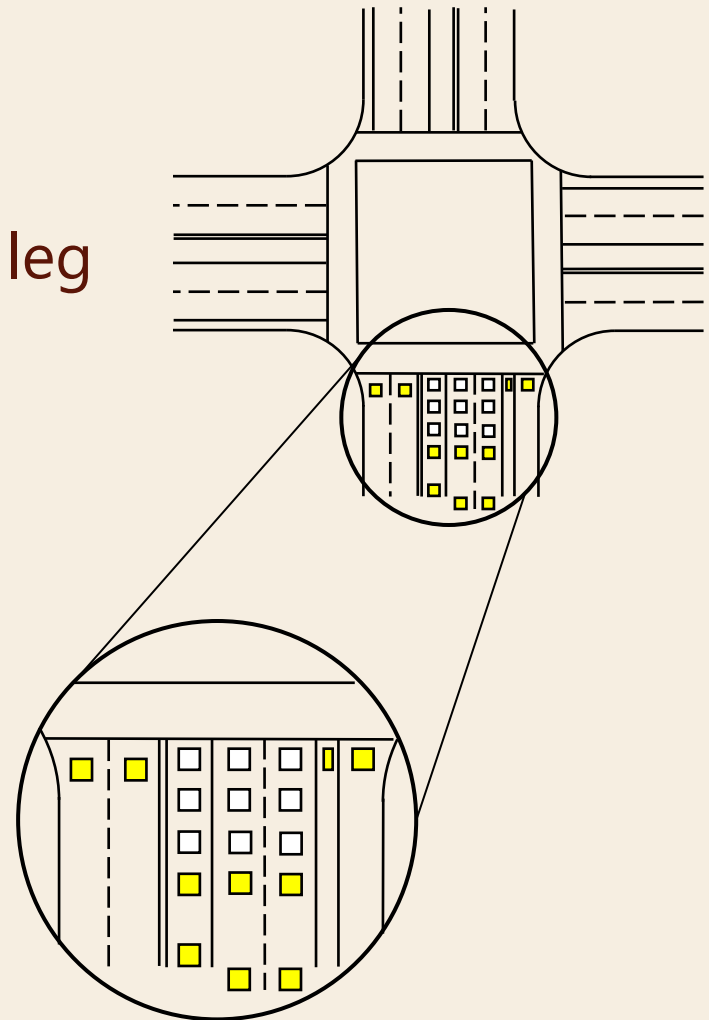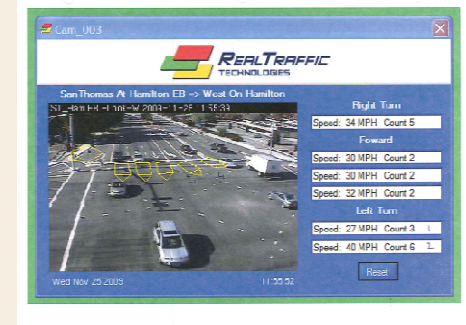
Signalized Intersection

- **Volumes and Occupancy**
  - Approach volumes
    - Understand trends for each leg of intersection
    - Use software to develop turning movements
    - Use advanced loops and far side loops

Signalized Intersection

- ## Volumes and Occupancy, cont.
  - Turning movement volumes
    - Can collect directly if loops/detection zones per lane
    - All technologies
    - Separate detector at back of stop bar loops or install new detector.
    - Standard video detection software to draw zones near stop bar
    - Video analytics software with standard, non-detection specific, video cameras (RTT, Econolite, Pelco, Trafficon, others)
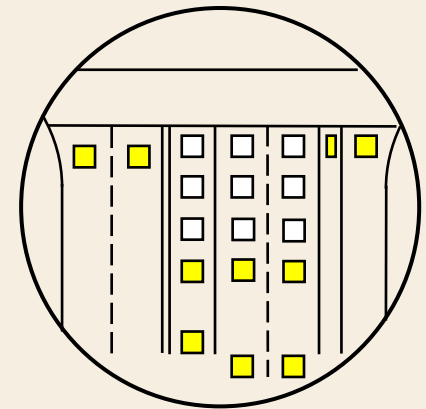
Signalized Intersection

- **Volumes and Occupancy, cont.**
  - Occupancy
    - % of passage time over detector
    - Used for traffic responsive or other type of adaptive operation
    - All technologies can obtain and is a function of the controller software
    - Preferred by lane per approach
    - Most accurate if advanced or far side detectors (not stop bar)

Arterial Mid-Block Data Collection

- Corridorwide performance measures
  - Segment volume
  - Speeds
  - Travel time
  - Occupancy
- Technologies
  - All options: Inductive loops, magnetometer, microloops, video, radar, microwave, sound, or infrared

Arterial Mid-Block Data Collection

- **Volumes and occupancy**
  - Inductive loops, magnetometer, microloops: single detector (loop, unit, device) per lane
  - Video, radar, microwave, sound, or infrared: Generally one unit for all lanes

- **Speed**
  - Inductive loops, magnetometer, microloops: Two detectors (loop, unit, device) per lane
  - Video, radar, microwave, sound, or infrared: Generally one unit for lanes

Arterial Mid-Block Data Collection

- **Travel time**
  - Obtained for detector unit software or system software (ATMS, PEMS type software)
  - Generally calculated by using speed values from detectors or travel time between adjacent detectors

Freeway Applications

- **Traffic Monitoring Stations**
  - Volumes
  - Speeds
  - Occupancy
- **Ramp Metering**
- **Traveler Information Systems**
  - Volumes
  - Speeds
  - Travel Times (probes)
  - Historical Information

Freeway Applications

- Detection not used for actuations or extensions
- Data collection
- Presence Detection
  – Time over the loop
  – Counts, speed and occupancy data
- Probes (Toll Tag Readers, Bluetooth)
  – ID, direction and location

Freeway Applications

- ## Loops
  - 6-foot square (typical)
  - Two loops per lane (occupancy and speed)
  - Single lead-in per loop (per lane data)

- ## Microloops
  - Alternative to inductive loops
  - Up to four sensors per lane
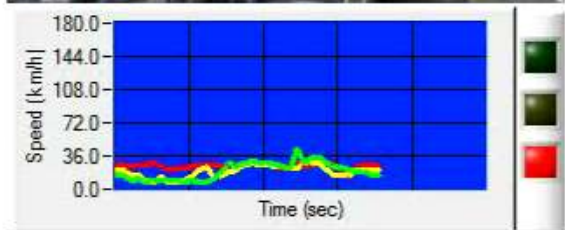 - Connect probes in series

Freeway Applications

- ## Video

  - Detection zones per lane
  - Length of detection zone
  - Viewing angle critical
  - Pavement reflection issues

Freeway Applications

- ## Magnetometers

  - Multiple sensors per lane

  - Pulse and Presence modes

  - Wireless comunications to roadside processor

Freeway Applications

Microwave

- Low-energy microwave radiation
- Detects vehicles traveling faster than a minimum speed
- Multi-lane coverage (side fire)
- Can average vehicle speeds over several lanes (511)
- Works best for unimpeded free flow speeds
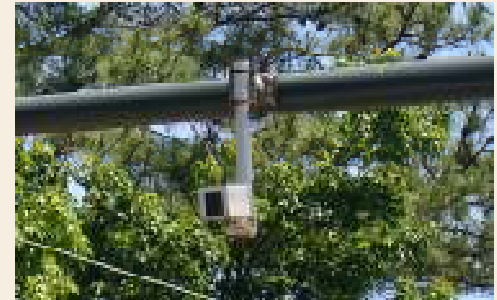
Freeway Applications

- ## Radar

  – Multi-lane coverage (up to eight lanes)

  – Good for freeway use with multilane coverge

  – Older pulse models used range bins for speeds

  – Some models have issues with large steel structures. (i.e. steel bridges)

  – Overhead conductors within beam cone can cause problems

Source: Electronic Integrated Systems, Inc. (EIS)

Freeway Applications

Sound (Ultrasonic)

– Most prevalent are passage and presence only

– More costly types also measure speed

– Range of 'sound area' basis for detection

– Capable of over height vehicle detection

– Environmental conditions can affect performance.

– Large pulse periods may result in inaccurate occupancy measurements

Freeway Applications

- ## Sound (Acoustic)

  - Passively detects acoustic energy (audible sounds) produced by vehicular traffic

  - Cold temperatures affect the accuracy

  - Not conducive with slow moving vehicles in stop and go traffic

Freeway Applications

- ## Infrared (Passive)

  – Sensor has reduced sensitivity in heavy rain, snow and dense fog

  – Need several passive sensors for speeds

  – Some passive models not recommended for presence detection

- ## Infrared (Active)

  – Covers multiple lanes

  – Fog and blowing snow affects accuracy - visibility is less than about 20 ft

  – Requires periodic lens cleaning

Freeway Applications

- ## Ramp Metering
  - Determine flows and gaps in the mainline traffic
  - Provide data to ramp metering system
  - Adaptive Ramp Metering

Freeway Applications

- **Toll Tag Readers**
  - Wireless
  - Passive
 - Data Transfer (GPRS link to 511 data collection servers)

Freeway Applications

Bluetooth

- Frequency band of 2.45 GHz.
- Each device has a unique 48-bit MAC address
- Class 1 = 100 meter range
- Class 2 = 10 meter range
- Sensors require high sensitivity and rapid acquisition time
- Range introduces 'circle of detection error' (bluetooth can be recorded several times for the same sensor)
- Accuracy comparable with toll tag readers
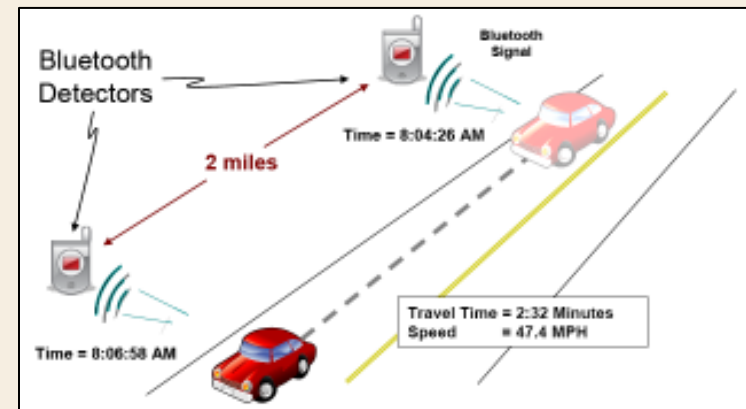
Freeway Applications

- **Bluetooth readings**

| Counter	MAC	Scan Time	Date	Time
0	00:04:76:C8:90:52	4.68829	20080910	170517
1	00:1E:7D:E7:6E:6D	4.68829	20080910	170517
2	00:05:4E:81:FC:87	4.88134	20080910	170522
3	00:04:76:C8:90:52	4.88134	20080910	170522
4	00:1E:7D:E7:6E:6D	4.88134	20080910	170522
5	00:04:76:C8:90:52	3.3137	20080910	170525
6	00:1E:7D:E7:6E:6D	3.3137	20080910	170525
7	00:1E:7D:E7:6E:6D	2.32605	20080910	170527
8	00:04:76:C8:90:52	4.23462	20080910	170532

Special Applications

- **Transit Detection Technologies**
  - Bus Detection (TSP)
  - Light Rail Detection
- **Adaptive Systems**
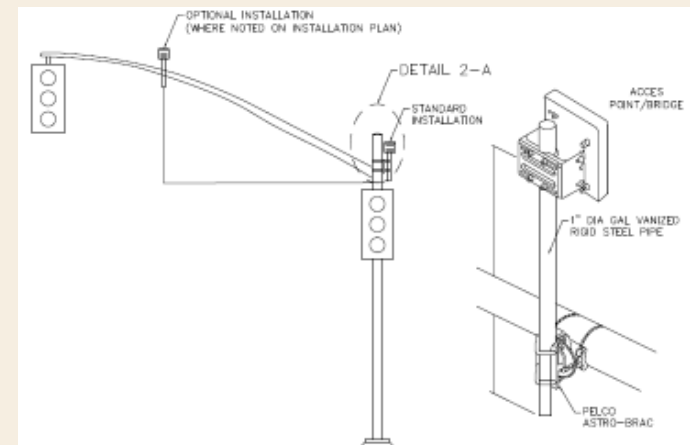
Transit Detection Technologies

- **Bus Detection (TSP)**
  - Optical (such as Opticom)
  - GPS
  - Loop detectors
  - Radio (WLAN)
  - Signal Interconnect for cascading calls
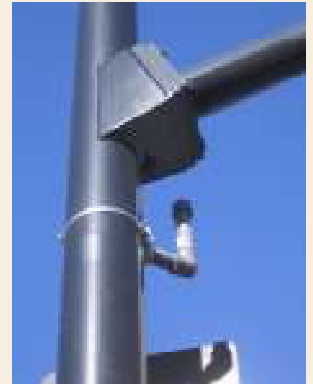
- **Light Rail Detection**
  - Preformed inductive loops
  - Check in and check out detectors

Adaptive Systems

- **Detection Requirements**
  - Lane by Lane
    - Count
    - Occupancy
    - Speed
    - Queue Lengths
  - Stopline and/or advanced – depends on the system

Adaptive Systems

- **Detection Technologies for Adaptive Systems**
  - Loops
  - Video
  - Magnetometers

Going green…

- Most side non-invasive detection methods can operate on solar power
- Quicker installation and set-up

Source: SpeedInfo, Inc.

Technology Evaluation

- Performance Measures
  - Accuracy
  - Reliability
  - Maintenance/Installation
  - Cost
- Type of application (intersection, midblock, etc.)
- Type of data (presense, count, speed, etc.)
- Location by location design specifics
  - Examples: Power available?, existing conduit?, # of lanes?, line of sight?, weather conditions?, pavement conditions?

Detector Technology Evaluation Matrix

Technology	Data Collected	Accuracy	Lane Closure for Installation	Mounting Configuration	Calibration Difficulty
Inductive Loop	•Volume •Speed •Occupancy •Classification	Excellent	Yes	Roadway Surface	Low
Wireless Magnetometer	•Volume •Speed •Occupancy	Very Good	Yes	Sensors in roadway surface; Access Point and Repeaters mounted	Low
Microloop	•Volume •Speed •Occupancy	Very Good	Yes	Roadway Surface	Low
Video Image Detection	•Volume •Speed •Occupancy •Classification	Good	No (Side Fire) Yes (Minor closure for overhead)	Overhead or Side Fire	Moderate
Radar	•Volume •Speed •Occupancy •Classification	Very Good	No	Overhead or Side Fire	Moderate
Microwave	•Volume •Speed •Occupancy •Classification	Very Good	No	Overhead or Side Fire	Moderate to High
Acoustic	•Volume •Speed (some)	Good	No	Overhead or Side Fire	Moderate
Infrared	•Volume •Occupancy •Speed (some) •Classification	Good	No	Overhead or Side Fire	Low

Detector Technology Evaluation Matrix

Technology	Maintenance Difficulty	Signalized Intersection Application	Arterial/Freeway Application	Power Supply
Inductive Loop	Moderate to High	Yes	Yes	DC Power
Wireless Magnetometer	Low	Yes	Yes	DC Power for Access Point; Battery for Sensors and Repeaters
Microloop	Moderate	Yes	Yes	DC Power
Video Image Detection	Moderate to High	Yes	Yes	AC Power
Radar	Low	Yes	Yes	DC Power or Solar
Microwave	Low	No	Yes	DC Power or Solar
Acoustic	Low	No	Yes	DC Power or Solar
Infrared	Low	No	Yes	DC Power or Solar

Generalized Costs

Technology	Intersection - Approximate Cost (per approach)[1]	Mid-block Arterial or Freeway Cost (single location) [2]
Inductive Loop	$8,000 - $10,000	$12,000 - $13,000[3]
Wireless Magnetometer	$10,000 - $12,000	$12,000 - $15,000[4]
Microloop	$8,000 - $10,000	$7,000 - $8,000[3]
Video Image Detection	$8,000 - $12,000	$8,000 - $12,000[3]
Radar	$13,000 - $15,000	$10,000[5]
Microwave	NA	$13,000[5]
Acoustic	NA	$8,000 - $10,000[5]
Infrared	NA	$15,000[5]

Assumptions:
1) Intersection Approach Cost: Assumes 1 left, 2 through, 1 right turn lanes, with advanced detection 200' from stop bar
2) Mid-block Arterial or Freeway Cost: Assumes 4 lanes of traffic in one direction
3) Assumes 2 loops/zones per lane for speed and 200' of conduit/cabling to the controller cabinet
4) Assumes 2 units per lane for speed
5) Assumes 1 unit with solar on existing pole with wireless to the controller cabinet

Questions?

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